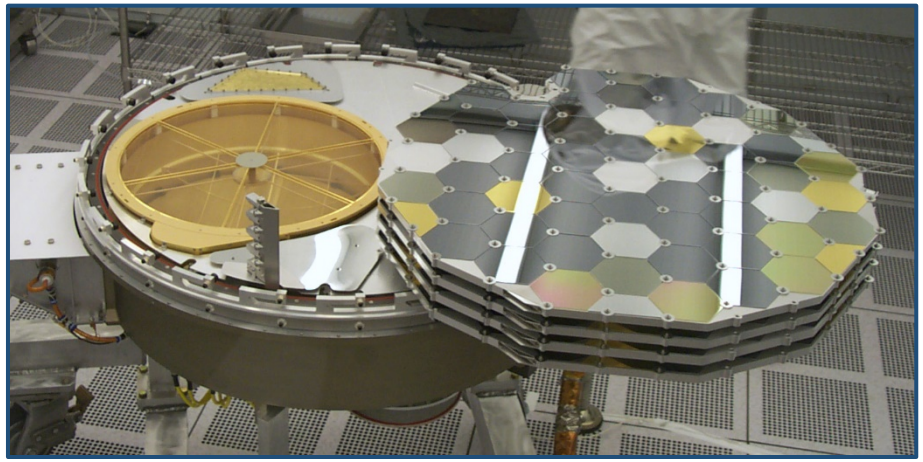


Genesis Solar Wind Sample Curation

WHAT?

Bulk Solar Wind
High Speed
Low Speed
CME

WHERE?

Earth-Sun L1

WHEN?

Dec 2001 to
March 2004

HOW?

Passive collectors:
Silicon
Sapphire
Aluminum
Gold
Germanium
Diamond-like-carbon

Concentrating collectors:
Silicon carbide
13C diamond
Diamond-like-carbon

WHY?

High Precision
Multiple Techniques
Regimes

Astromaterials Acquisition and Curation Office
NASA/Johnson Space Center
Judy Allton
Carla Gonzalez
Kimberly Allums-Spencer, Ph.D.

Last year's focus:

- Genesis ISO 4 cleanroom facility
- Outreach to heliophysics
- Celebration of success of our first virtual workshop

This year:

- History and evolution of collector characterization
- Collaboration with investigators on cleaning and cleanliness assessment of samples
- Usefulness of creating higher fidelity reference specimens

Status of collection

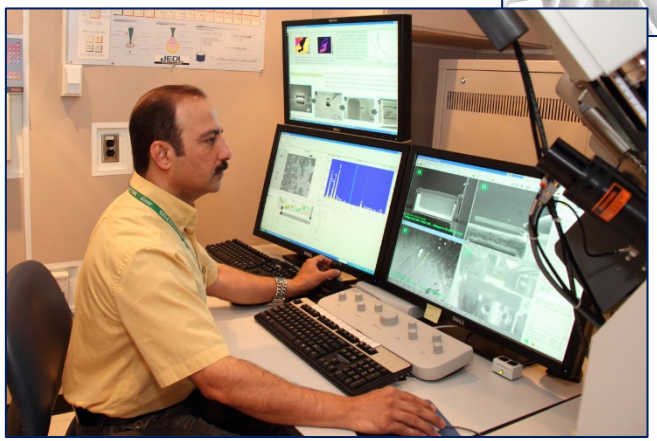
SAMPLES:
Total 4960
Characterized: 2856
Allocated: 736
2021 allocations 6

REFERENCE MATERIALS
Total 2000
Allocated 350

COLLECTOR CHARACTERIZATION TOOLS:
- High resolution optical imaging
- FT-IR
- Ellipsometry

What's new?
- FIB-TEM

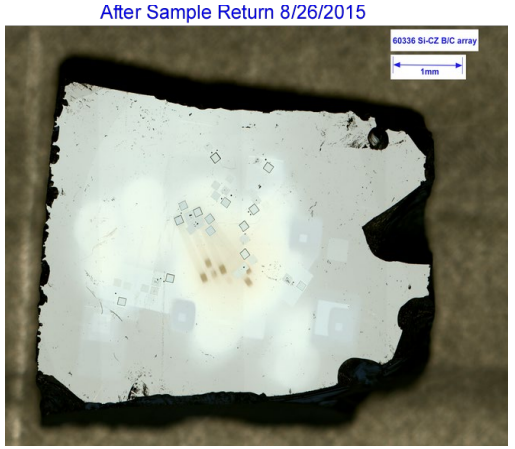
SAMPLE CLEANING TOOLS:
- UPW,
- UV ozone



Long history of collaboration for sample cleaning and cleanliness assessment

Don Burnett & Genesis Investigators –

- TXRF
- ToF-SIMS
- SIMS
- SEM
- Chemical cleaning
- CO2 snow
- Laser and ion beam cleaning
- Ion implantation
- SRIM modeling



60336 bulk SW silicon, example

2/26/2007	UPW cleaned 5min @40C at JSC
5/14/2013	Imaged using DM6000M at JSC
7/31/2013	SEM analysis at PSI
8/1/2013	Imaged using DM6000M at JSC
8/6/2013	UPW cleaned and imaged at JSC
8/13/2013	Aqua regia and hot xylene at Caltech
9/12/2013	Imaged using DM6000M at JSC
9/16/2013	UPW cleaned and imaged at JSC
10/14/2013	ToF SIMS analysis at Smithsonian
10/21/2013	Optical imaging at Smithsonian
11/12/2013	Low-vacuum nanoSEM at Smithsonian
11/12/2014	Imaged using DM6000M at JSC
11/24/2014	10 min RCA1 cleaning at Dartmouth
12/2/2014	25 min RCA1 cleaning at Dartmouth
12/4/2014	Imaged using DM6000M at JSC
12/4/2014	UPW clean 5min, 40C at JSC
12/4/2014	Imaged using DM6000M at JSC
12/18/2014	ToF SIMS analysis at Smithsonian

Goreva et al, 2015, 46th LPSC #2333

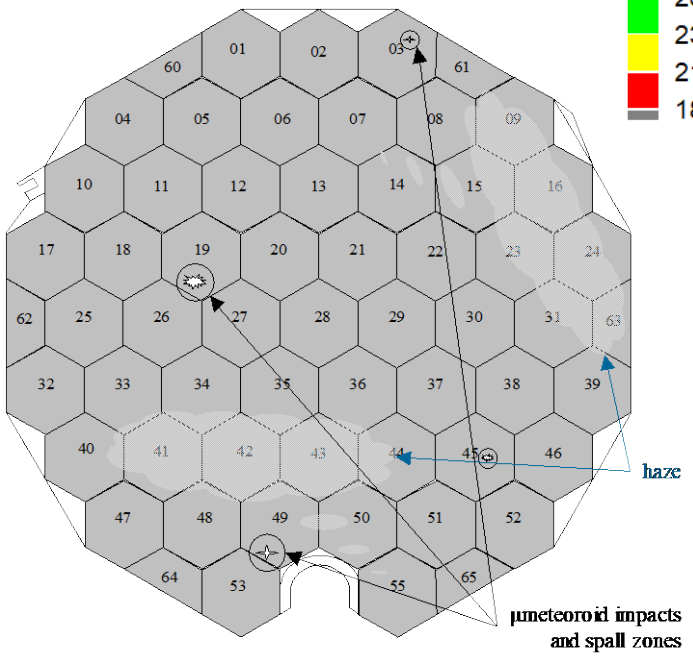
Sample Characterization History –
Pre-recovery plan for returned samples

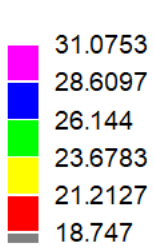
Basic Characterization of Hexagons
Solar wind regime
- Bulk
- Coronal mass ejection
- High speed
- Low speed

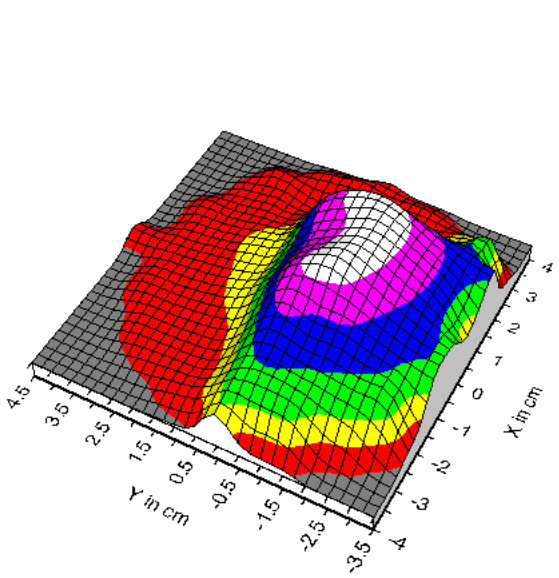
Collector Material
Manufacturer, batch, composition and purity. Identified by position in array.

Collector Cleanliness
- Optical inspection (impact craters, haze)
- Ellipsometry (molecular contaminants)

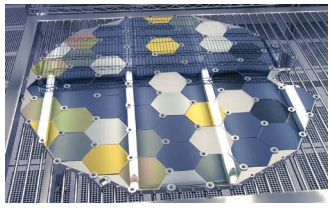
Mapping array for impacts and haze.
McNamara, 35th LPSC poster

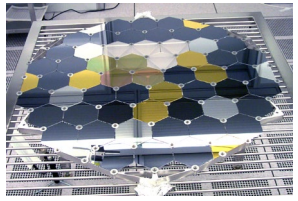


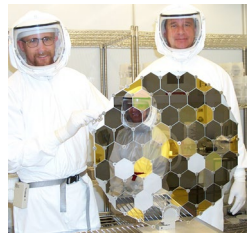


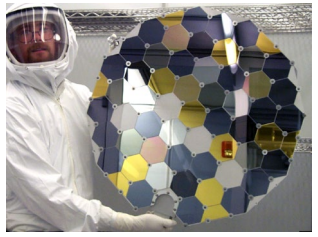


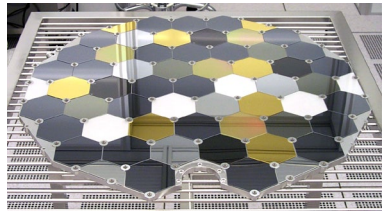
Mapping molecular contamination using ellipsometry. Test wafer was half masked. Thickness in Angstroms. J. A. Woollam Co.


BULK

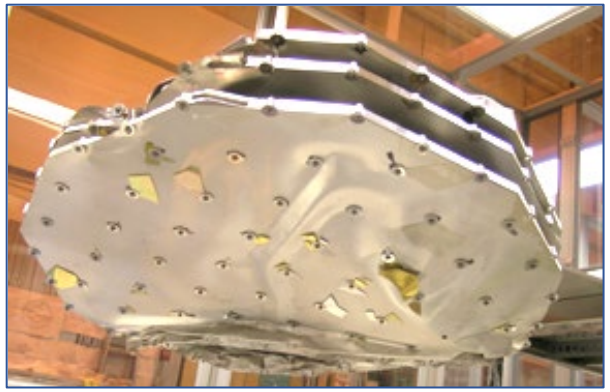

BULK


LOW SPEED

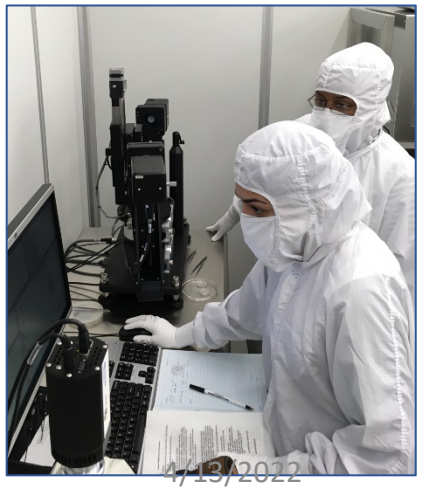

HIGH SPEED


CME

Sample Characterization History – Post-recovery practice



Returned with >10,000 fragments. Most unassociated with array position.



Characterization of Fragments

Solar wind regime (by fragment thickness)

- Bulk
- Coronal mass ejection
- High speed
- Low speed

Collector Material Identification

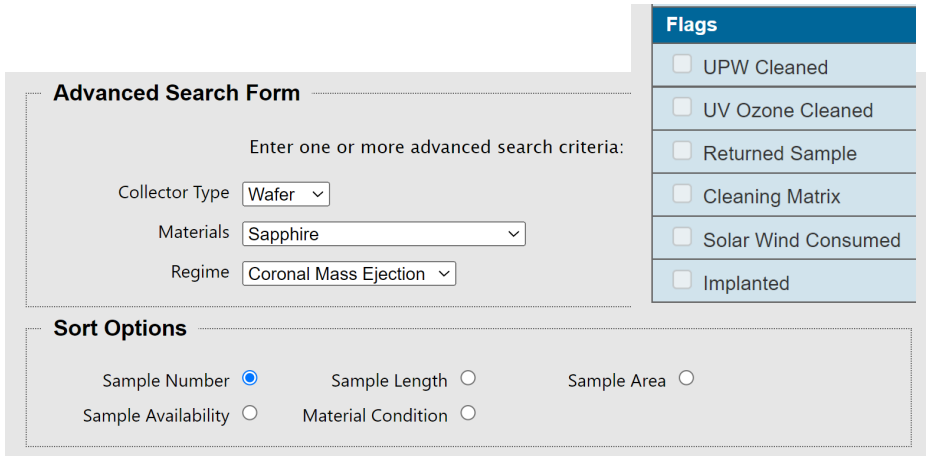
- Visually, microscope
- FT-IR (type silicon)

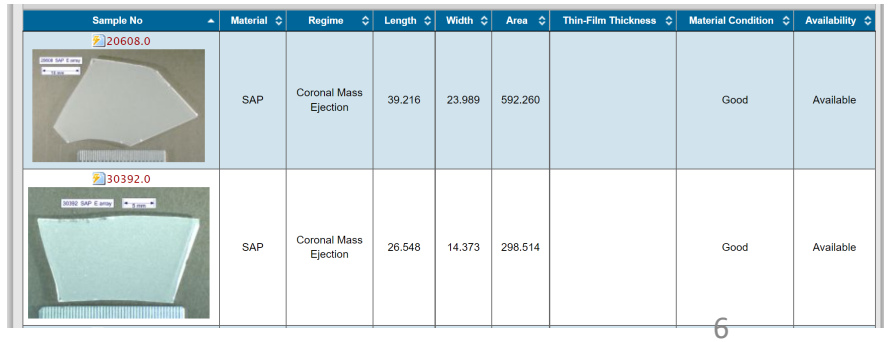
Fragment Image & Description

- Size and shape
- Condition and visual cleanliness
- Handling history
  - UPW
  - UV ozone
  - Implanted

Sample Characterization Published

- 2700 Samples in catalog

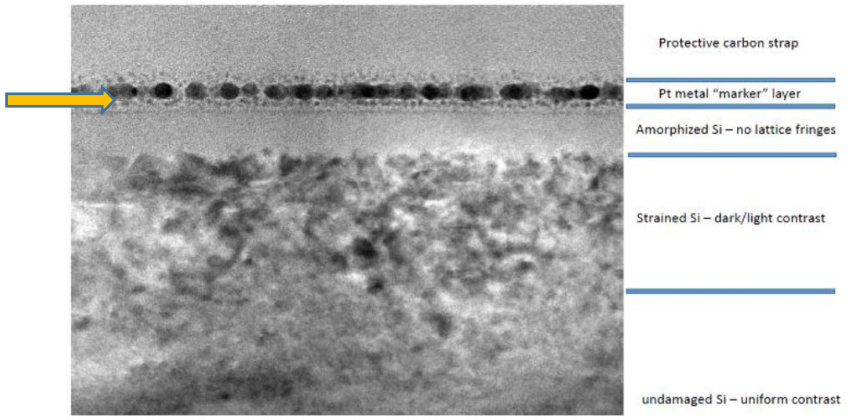




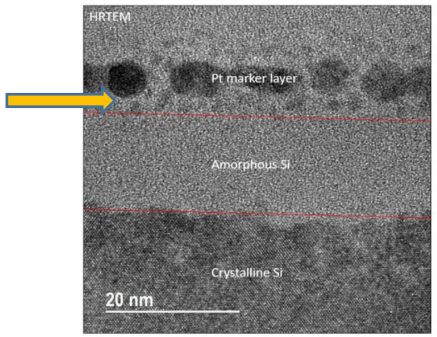
Sample No	Material	Regime	Length	Width	Area	Thin-Film Thickness	Material Condition	Availability
20608.0	SAP	Coronal Mass Ejection	39.216	23.989	592.260		Good	Available
30392.0	SAP	Coronal Mass Ejection	26.548	14.373	298.514		Good	Available

Sample Characterization – Evolving Trends

During analysis of Genesis-flown collectors, evidence that SW damage changed the solubility emerged. TEM cross-sections visualized the collector structural damage.



Bulk solar wind silicon 61202



Low speed solar wind silicon 20662
Allums et al (2020) 51st LPSC, #2768

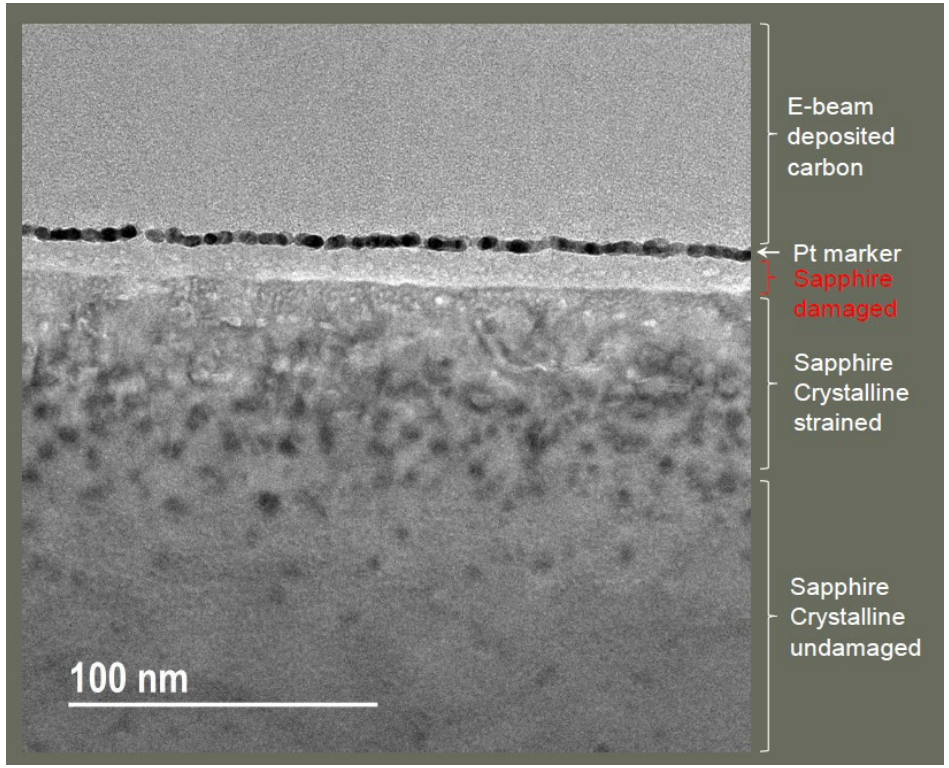
Lindsay Keller team to the rescue with FIB/TEM profiles showing **amorphization of silicon** in bulk solar wind and low speed solar wind samples.

Can we use the TEM profile data to develop a fast, non-destructive screening method for SW radiation damage?

Perhaps ellipsometry? Modeling to date on Genesis samples involve native oxide thickness, a-Si content, void content and surface damage layers, which can distinguish among the regimes, but is not consistent with the physical state seen in TEM cross-sections.

Sample Characterization – Evolving Trends

Also seen in sapphire! – upper 10 nm shows partial amorphization-high damage layer, and below crystalline sapphire is strained with vesicles.



Bulk solar wind sapphire sample 61527.
Keller, L. P. *et al.* (2022) LPSC #1196

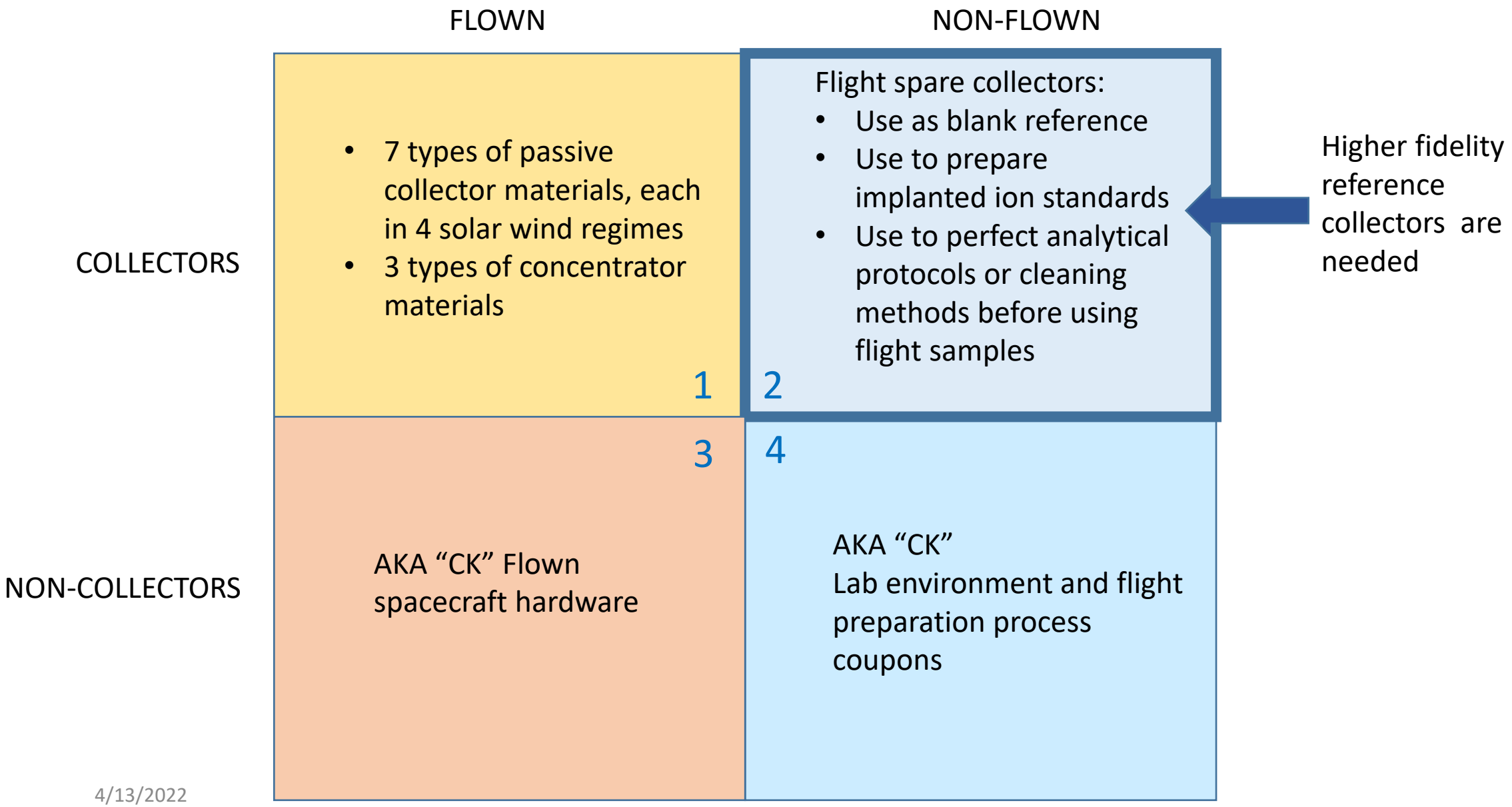
2018 Characterization Plan-

Acquire TEM cross-sections of all regimes in two materials silicon and sapphire for the purpose of developing a non-destructive ellipsometry screening process.

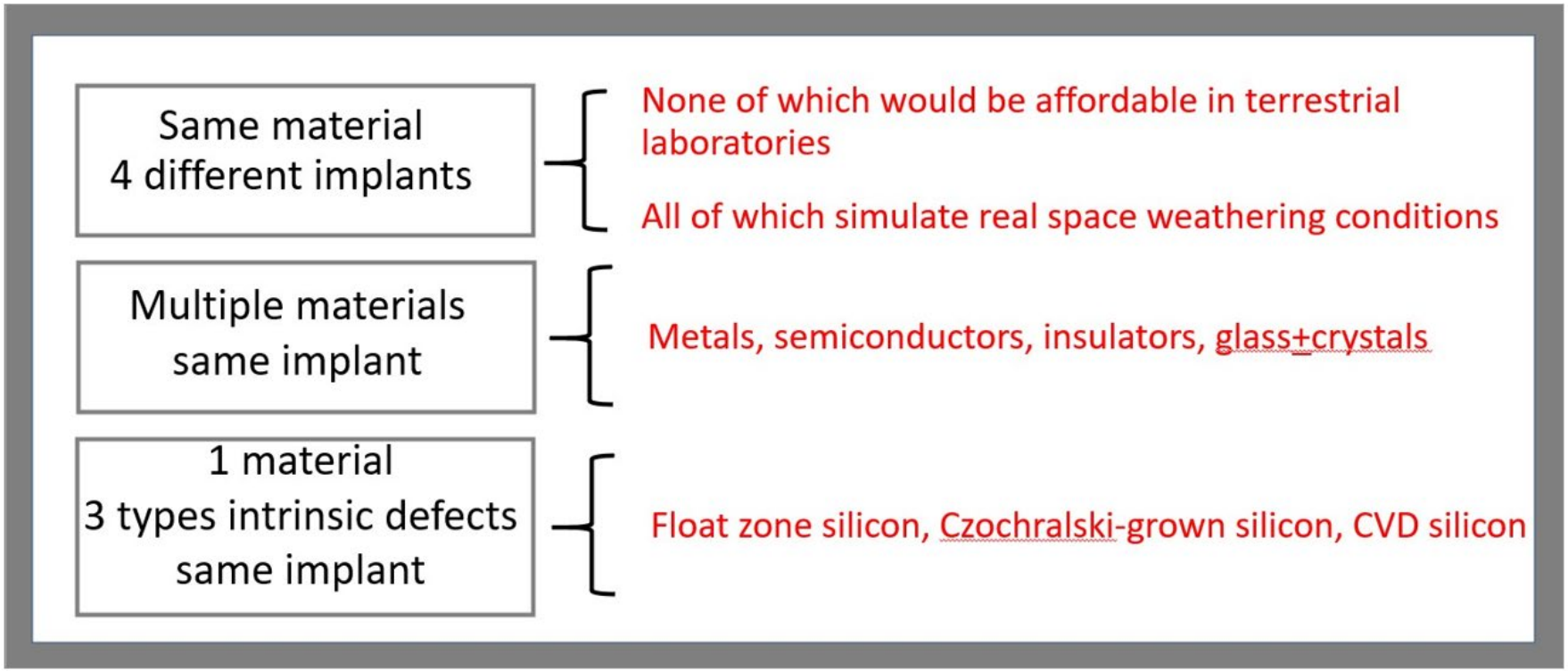
	Bulk SW	CME	High Speed	Low Speed
Silicon (CZ)	✓			✓
Sapphire	✓			

Past ellipsometry modeling of Genesis sapphire samples has focused on surface roughness. More data points are needed. Are other analytical tools available?

Genesis Solar Wind Collector Reference Materials



- **Genesis samples are unique**



Jurewicz *et al.* (2021) 52nd LPSC poster

2022 – looking ahead

- **Genesis samples are unique**
- **Accompanied by measured *in situ* solar wind from spacecraft**
- **Solar wind exposed materials behave differently than non-exposed reference materials**
- **Changes in structure can be visualized in TEM cross-sections**
- **Higher fidelity reference materials would enhance science value**

Thank you for your attention!